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**The Effect of Cognitive Load and Target
Characteristics on Soldier Shooting Performance and
Friendly Targets Engaged**

by David R. Scribner

ARL-TR-2838

November 2002

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Army Research Laboratory

Aberdeen Proving Ground, MD 21005-5424

ARL-TR-2838**November 2002**

The Effect of Cognitive Load and Target Characteristics on Soldier Shooting Performance and Friendly Targets Engaged

David R. Scribner
Human Research and Engineering Directorate, ARL

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THE EFFECT OF COGNITIVE LOAD AND TARGET CHARACTERISTICS ON SOLDIER SHOOTING PERFORMANCE AND FRIENDLY TARGETS ENGAGED

1. Introduction

This study was designed to address issues that may affect the shooting performance of a soldier under cognitive load. Specifically, this study was proposed to examine the ability of the soldier to perform friend-or-foe target discrimination, with varying target exposure times, friendly target signatures, and cognitive load conditions.

The dismounted soldier of the future will be “loaded” with more information processing tasks. It is conceivable that some increased level of cognitive tasking may be performed simultaneously with shooting tasks. The effect of shooting under cognitive load has been previously studied (Scribner & Harper, 2001). This study concentrated on the measurement of the workload of a friend-or-foe shooting task in a single- and dual-task scenario. It is imperative that the soldier not be overburdened mentally, which would result in decreased soldier survivability and lethality. The U.S. Army Research Laboratory (ARL) is the Army’s lead laboratory for studying shooting performance with small arms systems. The Warrior Performance Research Team of the Dismounted Warrior Branch of ARL’s Human Research and Engineering Directorate has a unique and highly regarded small arms shooting performance research facility (SASPRF) with which to collect human performance data during various live fire shooting conditions (see Figure 1).

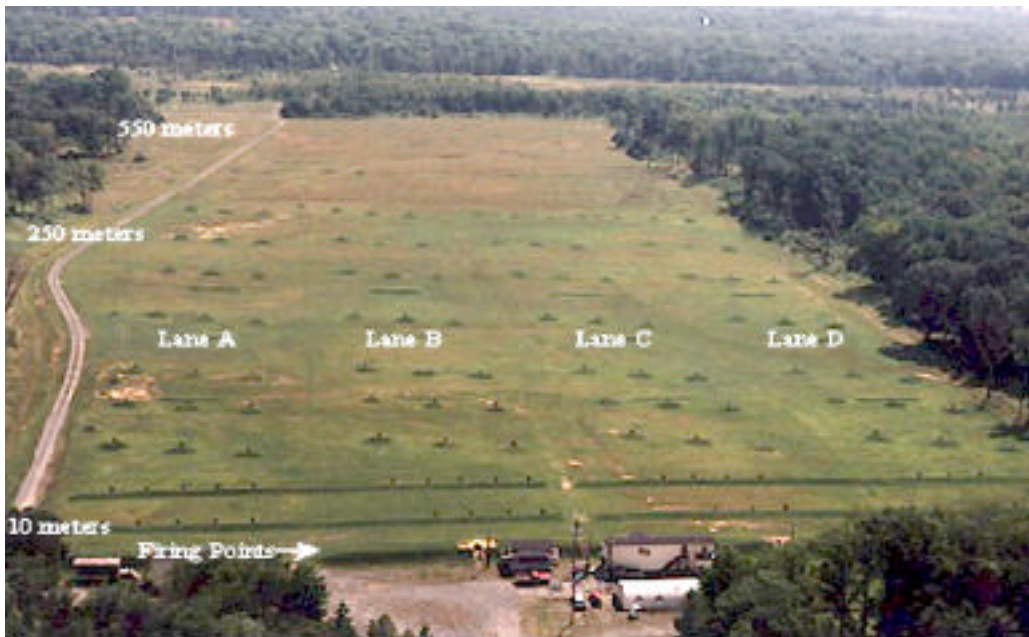


Figure 1. The small arms shooting performance research facility.

This study is relevant to the interests of the Army to enable future dismounted system designers (Land Warrior, objective individual combat weapon [OICW], combat identification systems, and objective force warrior) to design within the soldier's limitations to simultaneously conduct combat operations and cognitive processing functions. The cognitively loaded dismounted soldier must respond efficiently and effectively to single and multiple hostile target scenarios on the battlefield while maintaining awareness of several aspects of the intelligence and information systems (situational awareness), communication, and other pertinent battlefield intelligence. The results may provide researchers in the Department of Defense, academia, and industry with information regarding the efficacy of information systems for small arms shooters.

1.1 Current Dismounted Systems and Trends in the Dismounted Equipment Environment

The M16A2 rifle and M4 carbine are the current small arms issued to our fighting forces. These are relatively simple systems to use and are used well by the soldiers serving in our armed forces. The infantry soldier's job to date has been straightforward and free of high technology systems that could have increased cognitive workload and information processing requirements. However, the warrior's environment is changing in three distinct ways:

- The war-fighting environment is increasingly pointing toward urban or built-up areas (as seen in Haiti, Bosnia, and Somalia).

- The weapons that the soldier will use are becoming more sophisticated, such as the air-bursting capability of the OICW.

- The information being provided to the soldier is increasing, allowing more situational understanding with the potential for overload, which could prove deadly in an engagement with the enemy.

These issues clarify the need to develop systems that provide the soldier with situational awareness of terrain, friendly and enemy units, their movement and intentions, but at a minimal processing cost to the soldier's attentional resources. Newer dismounted systems such as Land Warrior and the Marine Corps' integrated infantry combat system propose concepts with which the soldier could have advanced communication, weapon connectivity, and other data at his or her disposal to fight more efficiently and with greater lethality. However, soldier knowledge requirements and workload will potentially increase because of the sophisticated nature of the future weapon and information systems.

There are limited attentional resources in a human. Systems must be designed so that critical information can be attended to when needed in an easy and quickly understandable format. Attentional resources of the war fighter must remain the center of focus for combat tasks that will require high levels of concentration and discrimination in environments such as military operations in urban terrain (MOUT).

It has been stated that the maximum target exposure time for soldier survival in a MOUT environment is 2 seconds. According to Sterne and Yudovitch (1955), riflemen dashing from a prone position run at a rate of 5.4 to 6.4 meters per second after the first 2 or 3 seconds. A report by Torre and Querido (1990) says that 18 meters is good estimate of the average distance at which a target may be exposed in MOUT environments. Together, these data state that a running target would be visible from 2.8 to about 3.3 seconds, on average. They also state that at ranges shorter than 60 yards, approximately 2 seconds are required to score a hit.

With this in mind, the current study used 2 seconds as a bottom range for target time exposure during some shooting trials. Four- and 3-second target exposures were also used in order to provide a range of target exposure times to assess the effect on soldier's target discrimination ability.

1.2 Models of Attentional Resources

Several theoretical models currently exist to describe the nature of human multiple task performance. The single-channel hypothesis (Telford (1931), Craik (1948), and Welford (1952) contends that when a person uses mental processes for one task, processes for another task must wait or be "put on hold" while the original task is performed. Kahneman (1973) stated predictions of the human attentional resource. His proposal was that there was a single undifferentiated pool of such resources. Kahneman (1973) also adds that performance decrements occur when concurrent tasks compete for access to the same structures. The postponement of needed mental processes accounts for decrements in performance under heavy workload (Gopher, 1993).

The other common and more recently popular theory is that of multiple resource theory. First outlined by Navon and Gopher (1979), this theory claims that various disjointed sets of processing resources are used in combination for the performance of individual tasks.

One basic qualitative model of attentional resources as proposed by Wickens (1984a) is illustrated in Figure 2.

Wickens (1984b) has elaborated on these assumptions by suggesting a three-dimensional taxonomy of resources based on stages, codes, and modalities of processing. Wickens identified a number of possible resource capacity channels based on (a) type of input and output modality (visual versus auditory input, manual versus vocal output); (b) code or representational format used by the operator (linguistic versus spatial code); and (c) stage of resource processing (encoding versus central processing). Wickens also proposed that three factors would impact performance:

- Resource competition of the task(s),
- Amount of each type of resource available to be allocated to the task(s), and
- Relative efficiency of the resource allocated to the task(s).

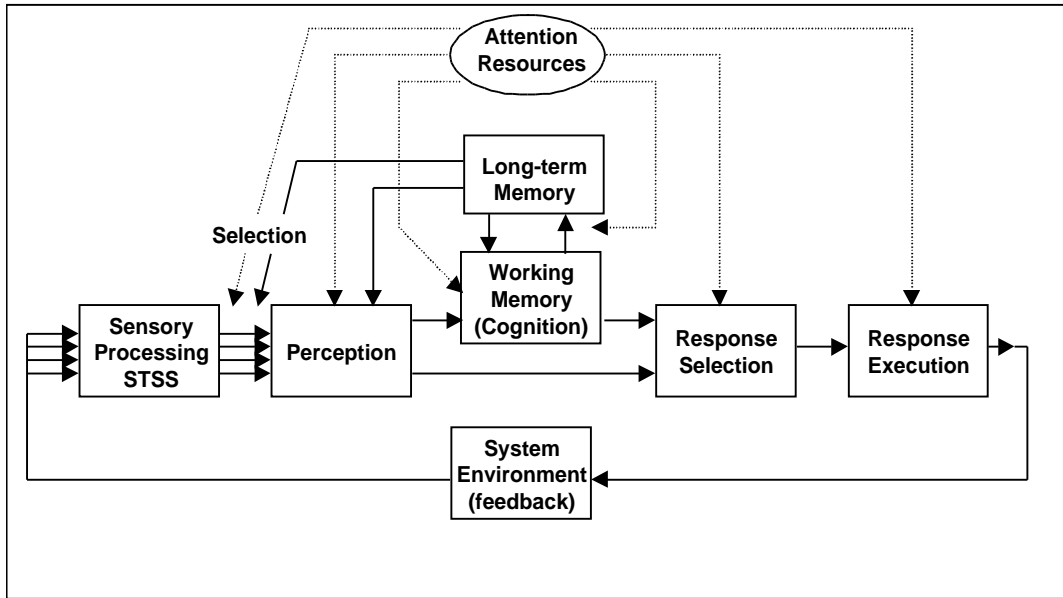


Figure 2. Model of attentional resources (Wickens 1984a).

The Wickens model of multiple resources appears to be the “best fit” of models available to describe the underlying processes in the experimental tasks performed in this study.

1.3 Primary and Secondary Tasks

For this study, the input and output modes of primary task and secondary tasks are listed in Table 1 in terms of Wickens’ (1984b) multi-dimensional model of multiple resource theory.

Table 1. Primary and secondary task properties

Task	Input Modality	Code Format	Output Modality	Resource Stage
Primary Shooting	visual	spatial	manual	encoding
Secondary Math Tasks	auditory	verbal	vocal	central processing

The primary task is shooting. Soldiers were instructed to shoot the best they could in every trial and to shed the secondary (mathematical problem solving) task if overload became an issue. The strategy used to cope with the dual-task scenario is thought to be time sharing.

Time sharing is the process by which humans react to the dual-task paradigm. The strategy of time sharing is used to perform tasks that are imposed simultaneously. Some of the differences in time-sharing ability may be attributable to practice or to basic time-sharing ability (Wickens,

1984a). Improved performance of a dual task can be said to be an increase in the automaticity of the task itself or of the increased time-sharing skills associated with practice (Damos & Wickens, 1980). It has also been said that an improvement in single task performance will contribute to reduced resource demand for dual task performance, based on improvement in single task component skills (Schneider, 1985; Schneider & Detweiler, 1988).

The issue of mental workload (MWL) measurement is important when one is talking about the cognitive capabilities of the soldier. One of the methods for measuring MWL in the past has been the use of the secondary task. The secondary task is used as an additional load to the primary task (Rolfe, 1973; Ogden, Levine, & Eisner, 1979). The primary task method is based on the argument that increasing MWL will cause a performance decrement in the secondary or primary task, depending on which task is to be maintained.

In this study, the primary task performance was emphasized. From a previous study that examined the effect of workload on secondary task performance (Scribner & Harper, 2001), it was shown that shooting is a task that affects the performance of a secondary cognitive task.

The secondary task is used to apply pressure on primary task performance (e.g., attentional demands from a dismounted warrior system) in which primary task performance during more difficult tasks will deteriorate more than performance of easy tasks (Knowles, 1963). This is also a measure of how much additional work a soldier can undertake while still performing the task to meet system criteria. Samples of such secondary tasks include arithmetic addition, repetitive tapping, choice reaction time, and critical tracking tasks.

A secondary task (auditory input, verbal output) was employed that would not interfere with the channels used for shooting (visual input, psychomotor output). This method was used in conjunction with Wickens' (1984b) multiple resource theory to minimize the workload channel interference. A primary-secondary task set was developed to maintain the least amount of channel interference between the visual, auditory, and psychomotor channels, as would be the case in an optimized future dismounted warrior system. It also allowed optimal time sharing among tasks for a dual-task scenario with the least amount of resource conflict. This would provide optimal performance during dual task workload. The math task was simple and did not require training, in comparison to a task that a soldier might perform over an intra-squad radio.

Some additional information states that auditory tasks tend to suffer more performance degradation in relation to visual tasks, as found by Massaro and Warner (1977). Note that auditory information is intrusive and is difficult to exclude, which is why it is used as a warning code. This may have secondary task performance implications for the dismounted warrior.

1.4 Subjective Workload Measurement

The subjective measurement of workload was also used. The subjective workload assessment technique (SWAT) is the most frequently cited workload analysis tool in the literature and was developed at the U.S. Air Force Harry G. Armstrong Aerospace Medical Research Laboratory.

SWAT, which is grounded in a multi-dimensional view of time load, mental effort, and psychological stress, was selected for this study because of the rapid nature by which subjective ratings could be collected over many experimental trials. Additionally, SWAT has been validated with the use of general mathematical problem-solving ability (the secondary cognitive task used in this study).

1.5 Shooting Scenario

The literature has ample pertinent shooting data with various types of weapon configurations, styles of training, and various conditions for novice and elite sport shooters and soldiers. However, before Scribner and Harper (2001), no literature in the past tried to quantify the MWL of a soldier while he or she is shooting or to quantify the limits of a secondary task during shooting.

There has been some research on the effectiveness of known distance (KD) shooting versus pop-up target shooting. KD shooting is the most widely used training and scoring system in the military today. Carey (1990) found that the correlation between KD scores and pop-up target scores was only 0.2. The live fire pop-up scenarios more closely resemble challenging combat shooting scenarios with shorter exposure times than do standard Army qualification tests or KD.

In addition to the pop-up scenario, a friend-or-foe decision was added to this shooting task. Twelve of 24 pop-up targets had a 6-inch white or gray circle at their centers to identify them as friendly, causing a desired “don’t shoot” decision (see Figure 3). Targets without a circle were designated as enemy targets, which were to be fired upon (see Figure 4).



Figure 3. “Friendly” target with 6-inch gray circle.



Figure 4. Friend-or-foe target signatures (E-type silhouette, white circle, gray circle).

The 6-inch white or gray circles (see Figure 4) were chosen instead of other colors and shapes because of their visibility at 300 m. The “shoot-don’t shoot” task was added because of the ever-increasing probability of the soldier’s encountering friendly, neutral, or non-combatants in a fighting environment. The targets were all exposed for 4, 3, and 2 seconds and fell if hit before the target exposure time expired. Each participant was carefully instructed to maintain shooting performance as his primary and most important task. He was also instructed to “shed” the secondary task of math problem solving and give preference to shooting and target discrimination when the situation called for a choice between which task to complete at a given moment of high workload.

This study was conducted as part of another study to identify and collect baseline data about standardized dismounted soldier tasks. Each soldier performed various tasks before this study such as a 4-km cross-country walk, an obstacle course run, hand grenade throw, individual movement technique, a sandbag lift and carry task, and a 1-mile road march. All soldiers performed all these tasks before shooting. Each soldier had a minimum recovery time of about 3 minutes before shooting the first trial.

1.6 Hypotheses

1. That shooting and secondary task performance decrements will exist when one is comparing no-load to cognitive load conditions.
2. That shooting and secondary task performance decrements will exist when one is comparing different target exposure times of 4, 3, and 2 seconds.
3. That shooting and secondary task performance decrements will exist when one is comparing different friendly target signatures of white and gray circles on E-type silhouettes.

4. That shooting and secondary task performance decrements will exist during all possible interactions of the variables listed in Hypotheses 1, 2, and 3.

1.7 Objectives

1. To determine if levels of cognitive workload, friendly target signature, and target exposure times will adversely affect a soldier's ability to discriminate friend-or-foe targets (shoot-don't shoot decisions) while he is shooting.

2. To determine if soldier psychological stress and cognitive workload ratings are affected by different levels of cognitive load, target exposure time, and friendly target signature while the soldier is shooting.

2. Methods

2.1 Participants

The participants were 12 U.S. Army soldiers, military occupational specialty (MOS) 11M (mechanized infantry), from Fort Hood, Texas. All participants met requirements for 20/30 visual acuity and were experienced with the M16A2. They also had required minimum weapons qualification. Their ages ranged from 18 to 34 years.

2.2 Apparatus

2.2.1 Demographic Questionnaire

A demographic questionnaire (see Appendix A) was given to collect age, gender, MOS, years in that MOS, experience with firearms, dominant hand, dominant eye, latest marksmanship qualification category and score, and how long since last qualification.

2.2.2 SASPRF (Shooting Task, Primary)

The shooting task consisted of a 24-target pop-up scenario with friendly (white or gray circular marking on the chest of the target) and enemy (olive drab green) E-type silhouette targets. Half of the targets were friendly and half were enemy. Ranges consisted of 50-, 100-, 150-, 200-, 250-, and 300-meter targets.

Target exposure times were 4, 3, and 2 seconds. Soldiers were in a foxhole supported position for all trials (see Figure 5). Appropriate hearing protection was worn at all times. M16A2 rifles with iron sights were used for this study. A safety briefing was given to each subject upon his arrival at the SASPRF, including the proper use of hearing protection (ARL, 1996).

The friendly target signatures, the right two images as seen in Figure 4, consisted of 6-inch circular plates placed at the center of mass of the E-type target silhouettes. The luminance levels of each friendly target signature, white and gray, were assessed. The luminance level for the plain surface of the target silhouette was also assessed. The luminance levels and luminous contrast ratios are all presented in Table 2.



Figure 5. Soldier in foxhole-supported firing position.

Table 2. Luminous contrast ratios for friendly targets^a

	Luminance Level cd/m ²	Contrast Ratio
Friendly Target Signature, white	2020	.77
Friendly Target Signature, gray	1290	.64
E-Type Silhouette, olive drab (background)	460	0

^aLuminance data were collected at 12:30 p.m., on a clear sunny day in January.

2.2.3 Mathematical Problem-Solving Task (Secondary)

The mathematical problem-solving tasks consisted of an auditory message presented through earphones, which the soldier processed and responded to before hearing a completion tone. This auditory task (listening to 20 mathematical addition problems and verbally producing an answer

after a tone) was used to create a uniform, forced reaction time, which did not require data analysis for reaction time but only accuracy. A moderate level of mathematical problem solving (Scribner & Harper, 2001) was chosen because of its workload, sensitivity, and perceived difficulty characteristics. The problems consisted of adding double digit and single digit numbers with carrying. The number of math problems correctly solved was calculated to score this secondary task.

2.2.4 SWAT

SWAT (Reid, Potter, & Bressler, 1989) was used to quantify soldier workload ratings during various conditions. SWAT has been validated with mathematical processing tasks of various levels for workload assessment. The definitions of these dimensions are

- Time load - the amount of time pressure *experienced* in the performance of the task.
- Mental effort load - the amount of attention or concentration required to perform a task.
- Psychological stress load - the presence of confusion, frustration, or anxiety that hinders the completion of a task.

The SWAT technique for measuring workload has two parts: (1) scale development and (2) event scoring. In scale development, a card-sorting exercise is conducted which is designed to determine the subjective conception of workload for each subject within the three dimensions just listed. During this sorting task, a subject sorts 27 cards that represent all possible combinations of the SWAT dimensions. By the subject arranging the cards in an order that represents the combinations of the dimensions that he thinks describe the lowest workload to the highest workload combinations, a scale can be created that reflects the way a subject (or a group) perceives the concept of workload. This defines the mathematical model for combining the three elements into a single dimension of subjective mental workload or conjoint analysis.

During event scoring, the subjects rated the experimental conditions using the dimensions of SWAT, one set of ratings for each event. Once the events were rated, the workload for each experimental condition was derived. A sample of the event scoring SWAT form is provided in Appendix B.

2.2.5 Subjective Rating of Events (SRE)

The SRE rating scale was used for assessing soldier global psychological stress. Fatkin, King, and Hudgens (1990) used this scale to aid in the assessment of firefighter stress levels. The SRE consists of a numerical scale from 0 to 100 to assess a soldier's stress at a specified point in time. An example of this form can be seen in Appendix C.

2.2.6 Weapon and Ammunition

The M16A2 rifle with iron sights and 5.56-mm M885 ball ammunition were used for this study.

2.2.7 Auditory Presentation of Information and Hearing Protection

Two digital moving picture experts group Layer 3 (MPEG3 or MP3) players with miniature “ear buds” were used to present auditory cognitive tasks. Single hearing protection ear “muffs” were placed over the subject’s ears to provide adequate hearing protection during shooting.

2.3 Procedure and Methodology

2.3.1 Independent Variables

- Level of cognitive load (none or moderate)
- Friendly target signature (white or gray)
- Target exposure time (4, 3, or 2 seconds)

2.3.2 Dependent Variables

- Completion of secondary cognitive tasks (percentage correct)
- SWAT workload ratings
- SRE stress ratings
- Number of hits scored and shot reaction time (time to first shot)
- Number of friendly targets engaged (friendly fire)

As part of the pre-test procedure, participants were given a volunteer agreement affidavit, which described the study and possible risks (see Appendix D). They were then screened for visual acuity with a Titmus II vision-testing device. If visual criteria were not met, the participants were excused from the study. Demographic data were collected and the participants were then asked to self-rate present baseline stress levels by using the SRE.

The subjects reported to the SASPRF to begin study participation. Subjects had previously completed an obstacle course run, 4-km cross-country course, sandbag carrying task, and a 1-mile road march. A safety briefing was given to each subject upon his arrival at the SASPRF, including the proper use of hearing protection. All subjects were provided with commonly “zeroed” rifles. They then trained under three, 18-target pop-up scenarios in which all targets were fired upon, and one 24-target friend-or-foe pop-up scenario in which friendly targets (white circles on targets) were not to be fired upon. This gave the subjects familiarity with the “shoot-don’t shoot” aspect of the experimental trials. A minimum of six targets hit was required in each of the first three trials; all subjects met training criteria.

Following this training, all 12 experimental 24-target trials were presented to the subjects. These trials were counter-balanced to minimize learning and order effects. Following each experimental treatment, each participant’s cognitive workload and stress levels were collected with SWAT and SRE (stress) data forms, respectively.

Participants were then fully de-briefed and given a point of contact for ensuing individual performance or results of the study.

3. Results

All data were analyzed with repeated measures analyses of variance (ANOVAs). *Post hoc* analyses consisted of Tukey's honestly significant difference (HSD) test. Means and standard deviations were computed for all dependent measures of shooting performance (shots, hits, and reaction times), cognitive workload assessment (SWAT), and stress (SRE). A modified Bonferroni procedure was used to determine a correction for family-wise error for all reporting dependent measures. This accounts for the values of significance in Tables 3 through 8, which appear significant at first glance but were not attributable to family-wise error correction. Only significant data (shown in bold) were plotted for each of the dependent measures.

Multiple regression analyses (see Appendix E) were also performed on the data sets to formulate prediction criteria for the tasks performed in this study. Forward stepwise multiple linear regressions (p to enter and remove = .05) were performed with the following variables as possible predictors: cognitive workload level (coded 0 = none, 1 = moderate) and shooting condition. These analyses were run to predict primary task performance, SWAT workload ratings, and SRE stress ratings. No values were missing; therefore, none were replaced.

3.1 Shooting Performance – Hit and Reaction Time (RT) Data

The ANOVA data are presented in Tables 3 and 4. Reaction time data are time to first shot. The hit data are depicted graphically in Figures 6 and 7. The reaction time data are depicted graphically in Figures 8 and 9.

Table 3. F-Test data for hits for target exposure time, target signature, and cognitive load

Condition	SS	df	MS	F	<i>P</i>
Target Exposure Time (TE)	843.59	2	421.79	127.28	.000
Target Signature (TS)	1.36	1	1.36	0.46	.50
Cognitive Load (CL)	0.44	1	0.44	0.11	.74
TE x TS	29.68	2	14.84	6.42	.006
TE x CL	9.59	2	4.79	1.53	.23
TS x CL	2.25	1	2.25	1.91	.19
TE x TS x CL	37.79	2	15.89	5.63	.01

SS = sum of squares df = degrees of freedom MS = mean square F = F-value P = probability

Table 4. F-Test data for RT for target exposure time, target signature, and cognitive load

Condition	SS	df	MS	F	P
Target Exposure Time (TE)	9.43	2	4.71	44.89	.000
Target Signature (TS)	0.07	1	0.07	5.28	.04
Cognitive Load (CL)	0.03	1	0.03	0.77	.39
TE x TS	0.13	2	0.06	3.38	.05
TE x CL	0.28	2	0.14	7.16	.004
TS x CL	0.0008	1	0.0008	0.056	.81
TE x TS x CL	0.13	2	0.06	3.38	.05

SS = sum of squares

df = degrees of freedom

MS = mean square

F = F-value

P = probability

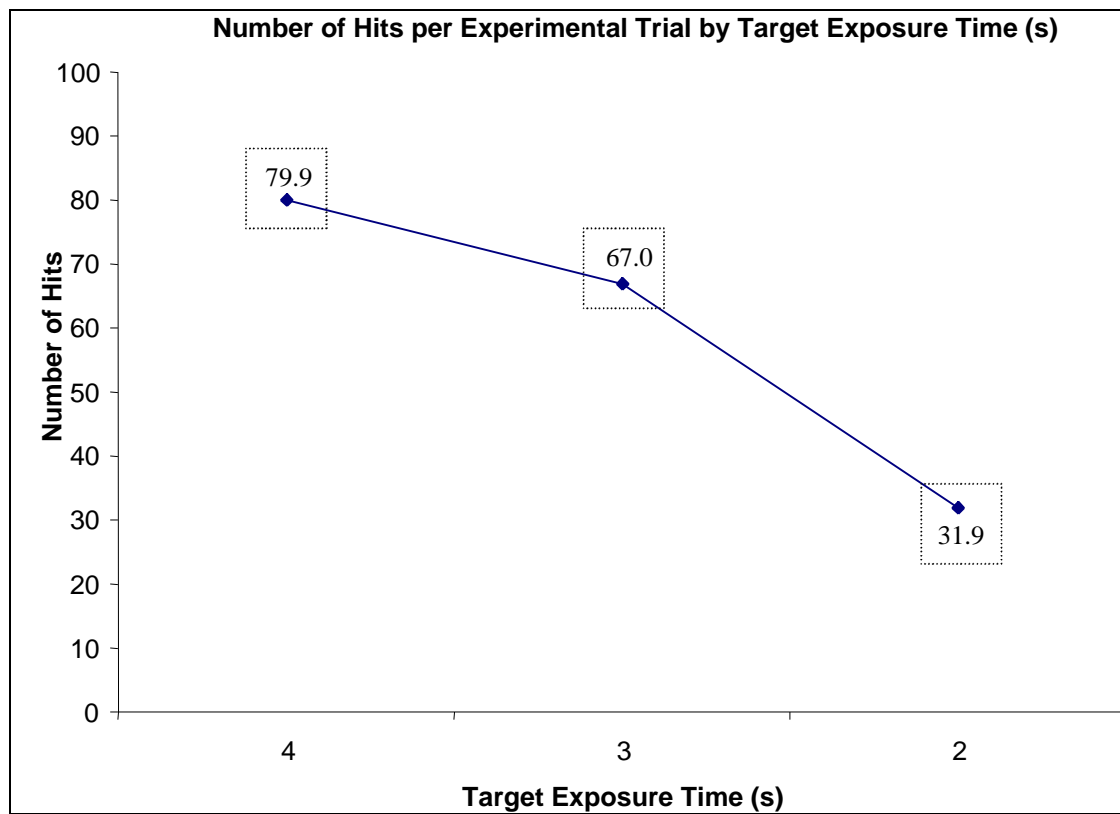


Figure 6. Percentage of hits by target exposure time.

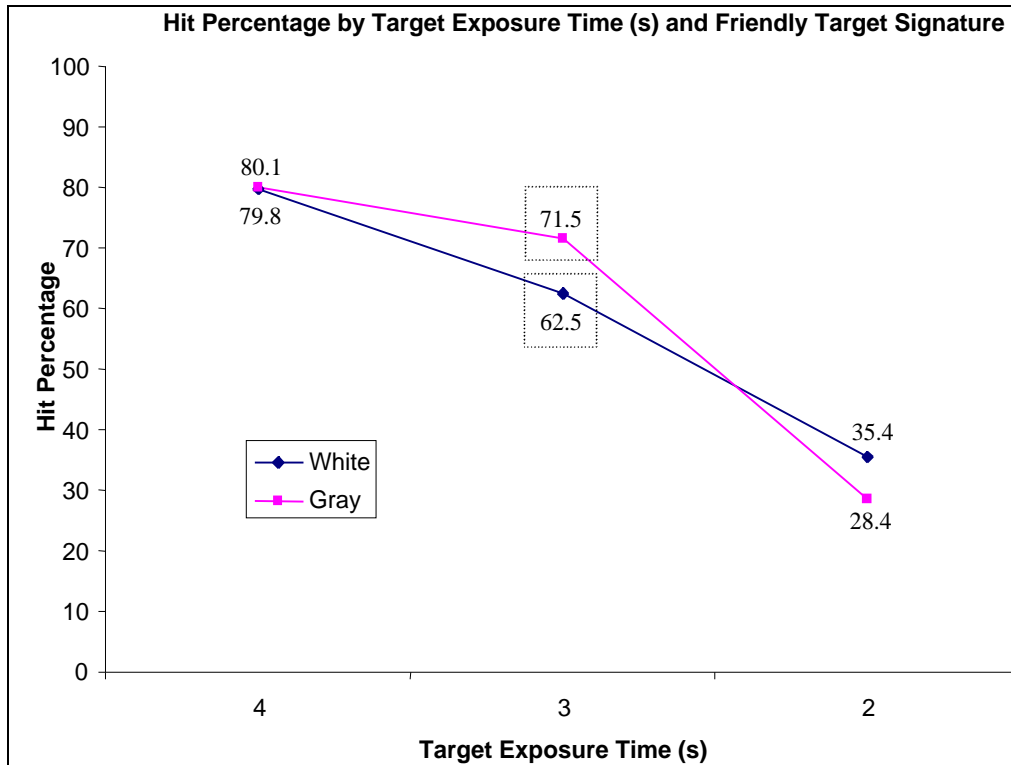


Figure 7. Percentage of hits by target exposure time and cognitive load.

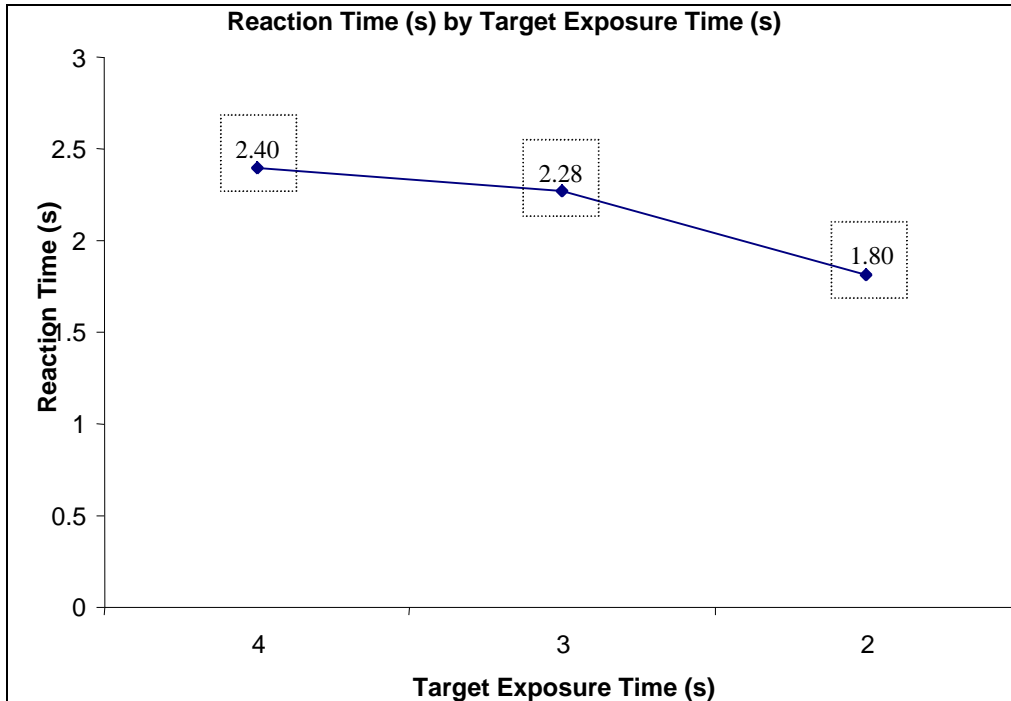


Figure 8. Reaction Time(s) by Target Exposure Time.

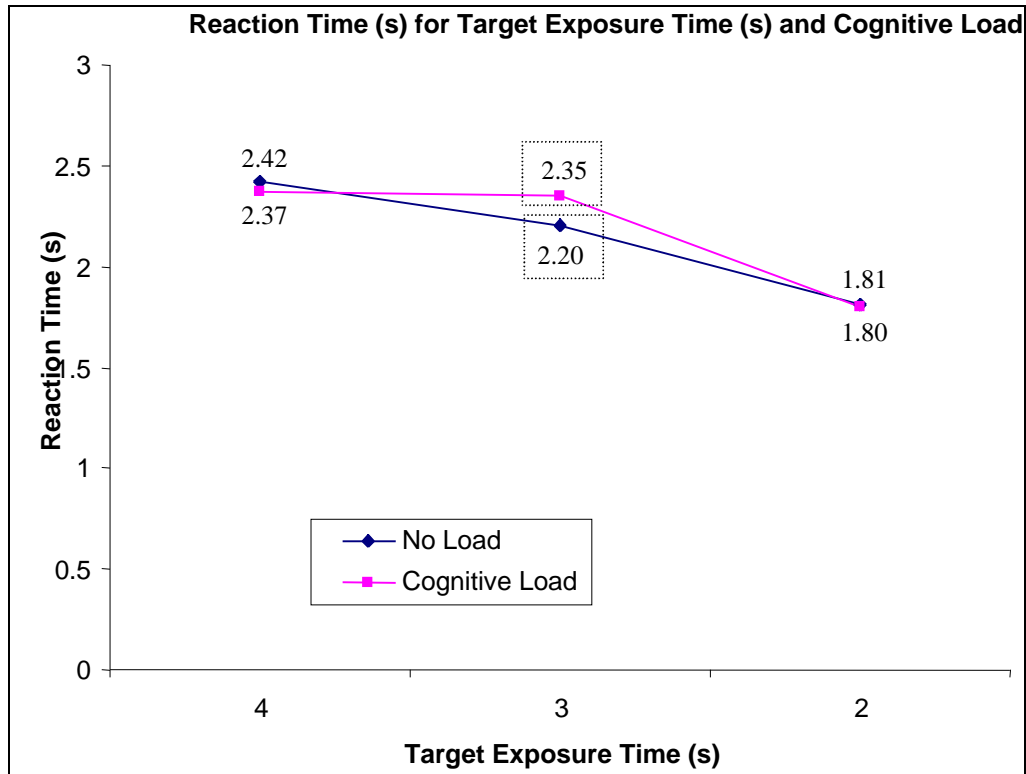


Figure 9. Reaction time(s) by target exposure time and cognitive load.

3.2 Subjective Rating of Events (SRE) Stress Ratings

Data for the SRE subjective stress ratings during the 24-target shooting scenario were statistically significant for the two-way interaction effect of target exposure time by cognitive load. The F-table is presented in Table 5. The data are presented in Figure 10.

Table 5. F-Test data for SRE stress ratings for target exposure time, target signature, and cognitive load

Condition	SS	df	MS	F	P
Target Exposure Time (TE)	428.16	2	214.08	2.72	.06
Target Signature (TS)	4.69	1	4.69	0.19	.67
Cognitive Load (CL)	870.25	1	870.25	5.62	.03
TE x TS	50.88	2	25.44	1.25	.30
TE x CL	2154.50	2	1077.25	9.11	.001
TS x CL	10.02	1	10.02	0.49	.49
TE x TS x CL	41.05	2	20.52	1.08	.35

SS = sum of squares

df = degrees of freedom

MS = mean square

F = F-value

P = probability

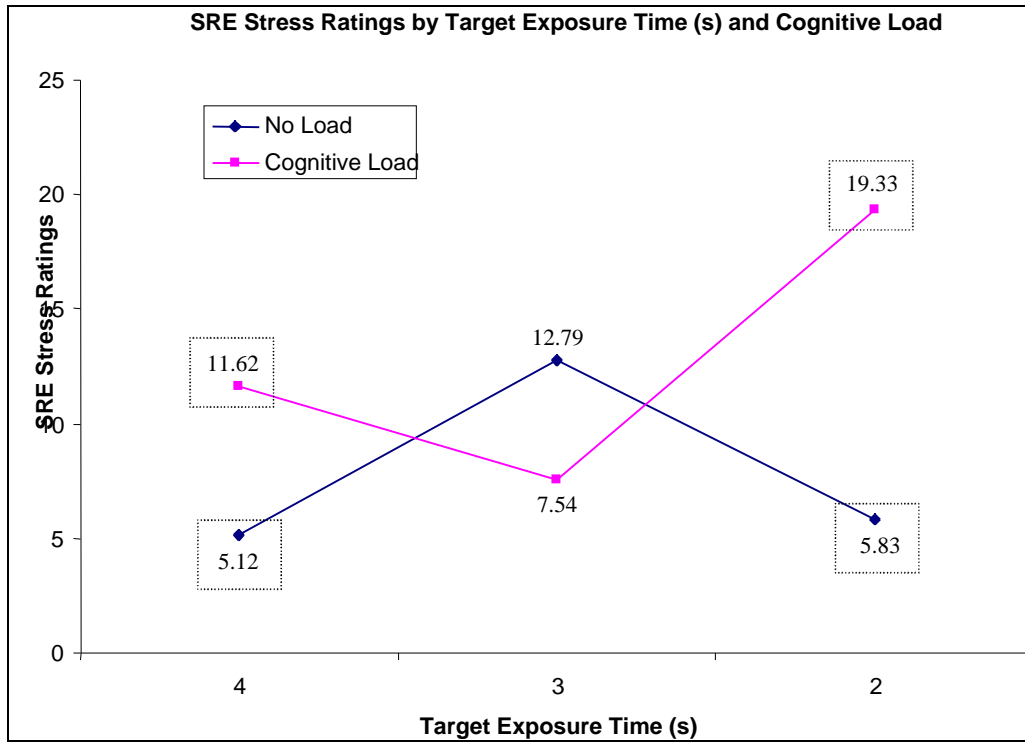


Figure 10. SRE stress ratings by target exposure time(s) and cognitive load.

3.3 Subjective Workload Assessment Technique (SWAT) Ratings

Data for the SWAT ratings during the 24-target shooting scenario were not statistically significant for all simple and interaction effects. The F-table is presented in Table 6.

Table 6. F-Test data for SWAT ratings for target exposure time, target signature, and cognitive load

Condition	SS	df	MS	F	P
Target Exposure Time (TE)	985.75	2	492.87	1.30	.29
Target Signature (TS)	301.89	1	301.89	2.04	.18
Cognitive Load (CL)	1725.71	1	1725.71	3.63	.08
TE x TS	159.12	2	79.56	0.66	.52
TE x CL	1160.06	2	580.03	2.73	.08
TS x CL	255.20	1	255.20	1.75	.21
TE x TS x CL	125.21	2	62.60	0.55	.58

SS = sum of squares

df = degrees of freedom

MS = mean square

F = F-value

P = probability

3.4 Math Task Performance

Significant task completion effects were found for only the simple effects of shooting and by level of math task difficulty. Tukey HSD *post hoc* tests revealed that all cells for the different math levels were significantly different from each other ($p < .01$). Statistically significant mean comparisons of interest have been identified with a dotted box around the measures for easy visual comparison. The F-table is presented in Table 7. The data are depicted graphically in Figure 11.

Table 7. F-Test data for mathematical problems solved for target exposure time, target signature, and cognitive load

Condition	SS	df	MS	F	P
Target Exposure Time (TE)	73.36	2	36.68	5.32	.01
Target Signature (TS)	60.50	1	60.50	20.06	.001
TE x TS	19.08	2	9.54	3.79	.03

SS = sum of squares df = degrees of freedom MS = mean square F = F-value P = probability

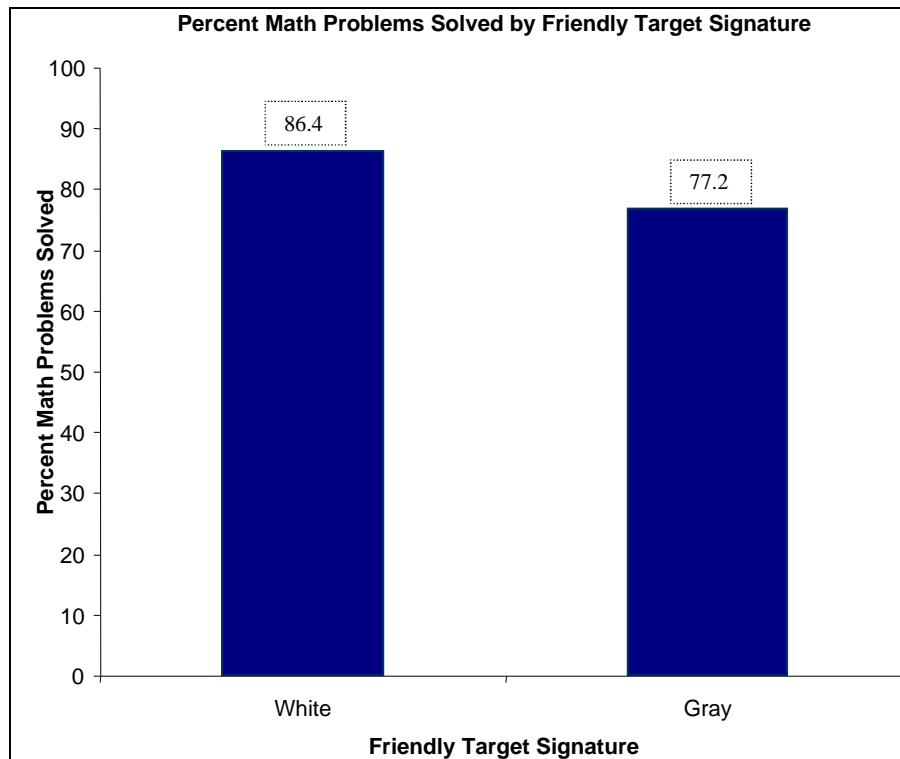


Figure 11. Mathematical problems solved for friendly target signature.

3.5 Shooting Performance – Friendly Targets Engaged

Data for the number of friendly targets engaged during the 24-target shooting scenario were statistically significant for the simple effect of cognitive load and the two-way interaction effect of friendly target signature by cognitive load. The F-table is presented in Table 8. Data are depicted graphically in Figures 12 and 13.

Table 8. F-Test data for friendly targets engaged for target exposure time, target signature, and cognitive load

Condition	SS	df	MS	F	P
Target Exposure Time (TE)	3.93	2	1.96	3.11	.06
Target Signature (TS)	0.84	1	0.84	1.24	.28
Cognitive Load (CL)	22.56	1	22.56	5.13	.04
TE x TS	1.01	2	0.50	0.63	.53
TE x CL	0.79	2	0.39	0.78	.46
TS x CL	2.50	1	2.50	5.09	.04
TE x TS x CL	4.59	2	2.29	2.62	.09

SS = sum of squares

df = degrees of freedom

MS = mean square

F = F-value

P = probability

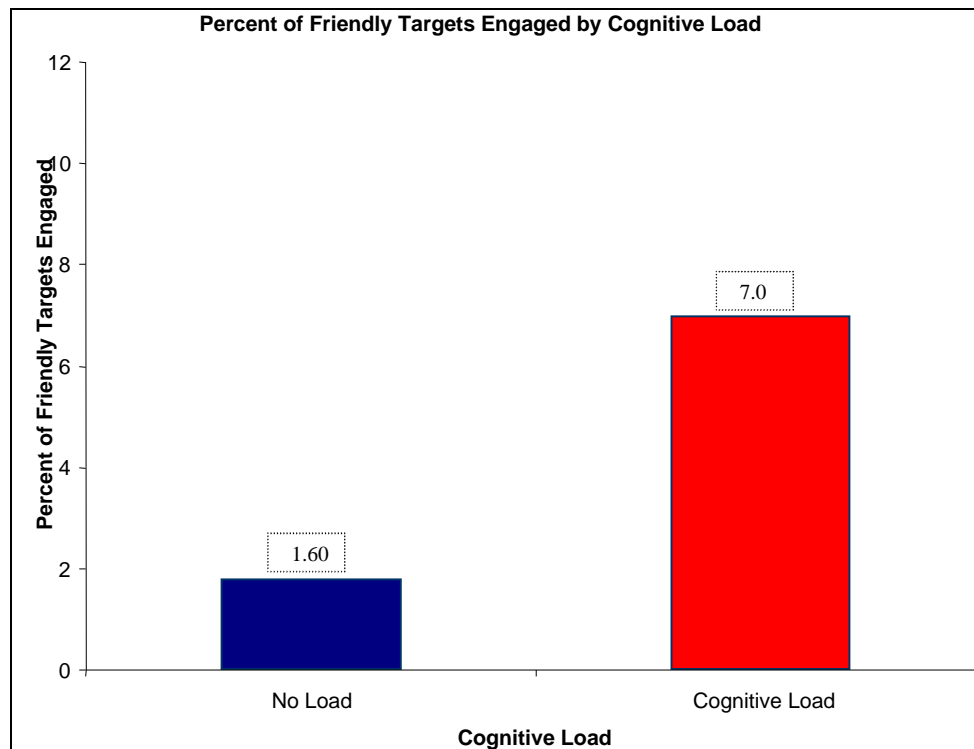


Figure 12. Percent of friendly targets engaged by cognitive load.

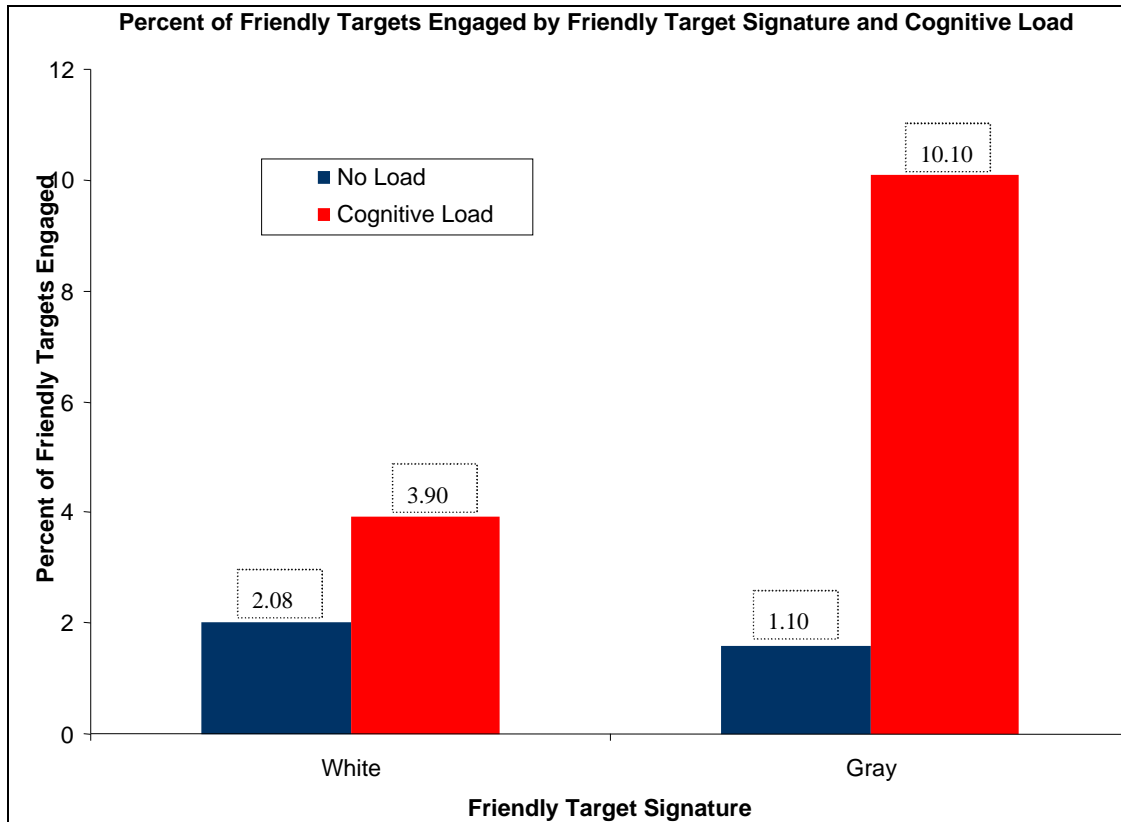


Figure 13. Percent of friendly targets engaged by friendly target signature and cognitive load.

3.6 Correlation Data – Armed Services Vocational Aptitude Battery and Performance Data

Data for the Armed Services Vocational Aptitude Battery (ASVAB) were collected for each soldier. The 10 sub-scale scores in the ASVAB were correlated with three main performance measures in the study. The sub-scale scores were general science, arithmetic reasoning, word knowledge, paragraph comprehension, numerical operations, coding speed, auto and shop information, mathematics knowledge, mechanical comprehension, and electronics information. Two composite scores, verbal expression (which consists of word knowledge + paragraph comprehension) and the Armed Forces Qualification Test were also used. The dependent measures of targets hit, friendly targets engaged, and math problems solved during shooting were correlated with the ASVAB score data. Table 9 lists the significant correlation coefficients values found between ASVAB scores and main performance measures.

Table 9. Correlation data for main performance measures and ASVAB scores

Variable 1	Friendly Targets Engaged +	Friendly Targets Engaged +	Friendly Targets Engaged +	Math Problems Solved +	Targets Hit +
Variable 2	Numerical Operations	Coding Speed	Verbal Expression	Verbal Expression	Coding Speed
Pearson R	-.179	-.192	-.246	-.304	.179
Significance	.031	.021	.003	.010	.032
N	144	144	144	72	144

4. Discussion

It is apparent that target exposure time, friendly target signature, and cognitive load had significant statistical effects at various levels for many of the dependent variables. The effect of cognitive load and friendly target signature had the most striking and meaningful data. The ability of soldiers to correctly identify potential targets and to decide whether to shoot, based on these identifications, is clearly affected by the mental workload that the soldiers were placed under in this study. In other words, the higher the mental workload experienced by the soldier, the more mistakes in target discrimination that will occur, as evidenced in this report. The SRE stress ratings support the friendly target engagement data by showing a clear increase in reported stress under cognitive load. Although these stress ratings are not considered “high,” they are significantly different from the no-load stress ratings.

The second objective of this study was to determine if soldier psychological stress and cognitive workload ratings are affected by different levels of cognitive tasks during shooting; this objective was also successfully accomplished. A disparate effect was found from the study conducted by Scribner and Harper (2001). The SRE stress rating was found to be much more sensitive to the shooting conditions than were the SWAT workload ratings. In fact, no significant SWAT workload ratings were found for any of the simple or interaction effects. However, the dependent variables that were sensitive to the cognitive load variable were reaction time, SRE stress ratings, and friendly targets engaged. All dependent variables were sensitive to friendly target signature except the SRE stress rating. All dependent variables were sensitive to target exposure time except the percentage of friendly targets engaged.

4.1 Shooting Performance - Friend-or-Foe Discrimination

The number of friendly targets engaged under cognitive load as compared to no cognitive load increased by approximately 3 times. The percentage for no load to loaded increased from 1.6% to almost 5%. This is a highly practical finding that should be considered by dismounted warrior systems and by all Army and other services' systems. The effect of cognitive load in this case is also considered quite conservative. It is projected that in a dual-task scenario that was channel competitive, such as two visual tasks, the percentage of friendly targets engaged would dramatically increase over 5%.

Note that the gray friendly target signature, which increased workload because of higher discrimination difficulty and longer target identification time, increased friendly fire engagements for non-loaded to loaded from 1.2% to almost 10%. It is thought that the white friendly target signature was too easy a discrimination task because of the high contrast that it provided on the E-type silhouette.

4.2 Shooting Performance – Hits and Reaction Time (RT)

The hit percentage for target exposure time showed a clear downward trend from 75% to 32% (4 seconds to 2 seconds, respectively). The effect for hit percentage under target exposure time and friendly target signature shows an increased hit percentage for gray at 3 seconds and white at 2 seconds. These data are thought to be an anomaly and cannot be explained.

It is interesting to note that RT decreased steadily for target exposure time. This is expected in order for the soldier to make the shot before the target disappeared. Another interesting note is that for target exposure time by friendly target signature, RT was consistently significantly lower for gray friendly target signature at 4 and 3 seconds. There was no statistical difference at 2 seconds. This might be accounted for by the Yerkes-Dodson effect (1908). Higher psychological arousal rates might have increased performance for the gray friendly signatures.

4.3 Secondary Task Performance (Mathematical Addition Problems)

The percent of math problems solved during shooting varied significantly for target exposure times of 4 and 2 seconds. The percentage decreased from 86.5% to 74.7%. The simple effect of target exposure time was enough additional pressure on the secondary task to show a significant difference in increased cognitive load, as shown by the task completion data.

The percent of math problem completion was significant for the friendly target signature variable as well. The percentage decreased from 86.4% to 77.2% for white and gray friendly target signatures, respectively.

4.3.1 SWAT MWL Ratings

No SWAT workload ratings were significant. It appears that the SWAT was not sensitive enough to these particular tasks to show differences or that subjects were not rating any perceived workload differences for these trials.

4.3.2 SRE Stress Ratings

The SRE stress rating data were significant for an interaction of target exposure time and cognitive load. This SRE was particularly useful in this study as one of the few dependent variables to be sensitive to cognitive load changes. The trends for the significantly different data points lie at 4 and 2 seconds. The trends for no cognitive load vary between 5.12 and 5.83 (of 100 possible) for 4 and 2 seconds, respectively. The trends for cognitive load vary between 11.62 and 19.33 (of 100 possible) for 4 and 2 seconds, respectively. These differences are seen in Figure 10. The data at 3 seconds were not significantly different.

4.3.3 Modeling Data

For the purposes of future performance, workload, and stress modeling work, multiple regression data for the various independent and dependent variables have been provided in Appendix F of this report. It is suggested that predicting performance of a cognitive task alone (single task) and under shooting (dual task) conditions can be done with the data provided. SWAT MWL and SRE stress ratings could be predicted as well. It is important to note that the tasks should be chosen carefully and that they would be similar in scope and difficulty to apply the regression models.

Workload estimates, workload formulas, and task flow networks have also been provided in Appendices G, H, and I, respectively. This information could be used in future workload modeling efforts to establish workload, general stress, or shooting performance during various conditions.

4.3.4 Correlation Data

Significant negative correlation coefficients were found for friendly targets engaged and the ASVAB subscales of numerical operations, coding speed, and the composite score of verbal expression (see Table 9). A similar finding was revealed for the number of math problems completed during shooting and verbal expression. An additional positive correlation was found between the number of enemy targets hit and coding speed. The relationship between the ASVAB subscales of numerical operations and coding speed with the main performance measures is easy to understand under the assumption that increased workload is accommodated more easily by individuals with higher mental coding and operation speeds. However, the high correlations between the ASVAB composite score of verbal expression and friendly targets engaged as well as number of math problems solved are more difficult to explain. The only general explanation that can be formulated at this time is that this component is related to overall intelligence in the area of mental accommodation to workload.

5. Conclusions

It can be stated that cognitive load does cause an increase in shooting error (friendly targets engaged), stress ratings, and an increase in reaction time. There are now causal data for system designers to consult in order to more prudently design soldier information and command, control, communications, computers, and intelligence systems. It must be reiterated that the data in this study are extremely conservative, and estimates must be made that include the effect of stressors in combat and more competitive channel interference. A future study will examine the effect of the same workload-inducing level in a visual presentation mode. This should demonstrate the effect of channel interference on friendly targets engaged. Cross-modality attention is the attention of resources to more than one sensory modality. In this proposed future work, both visual and auditory attention will be required. It is known that a redundant target code or one that uses more than one sense can speed processing time (Miller, 1991). Visual dominance is a concern because of the highly developed nature of the visual system (Jordan, 1972).

The gray friendly target signature proved itself to be a more mentally demanding discrimination task than the white target signature. This also demonstrates that even a conservative reduction in the strength of a friendly target signature will contribute to higher levels of workload and increased decision-making time. More realistic camouflage patterns should most certainly be more difficult to discriminate between and will be used in the ensuing study.

The decreasing target exposure times have historically produced decreases in the number of shots taken, hits made, and RT on the outdoor SASPRF. It is now known that the forced reaction time constraint contributes to increased stress ratings when linked to cognitive workload as well. The decreased target exposure times also increase cognitive workload, as can be demonstrated by the significantly decreased math problem solutions.

It is interesting to note that friendly target engagements might be predicted with the use of the ASVAB sub-scales of numerical operations, coding speed, and the composite of verbal expression. It remains to be seen whether personnel will be selected for their ability to cope with higher levels of workload during battlefield conditions.

Overall, this research, with the research of Scribner and Harper (2001), clearly demonstrates the need for information system designers to minimize human error and workload as much as feasible.

It must be decided how to best employ wearable computer systems in the battlefield environment. The dual-task scenario and information should be especially important to the designers of future dismounted warrior systems. These designers should be aware of the personal

characteristics of the system as well as how the system is to be employed in combat. It can be expected that the system will be used in one of two ways:

- Serially - the soldier will perform (a) a task within the information system, (b) an exterior combat task, and then (c) another system-related task, “flipping up” the display in between combat tasks to maintain full immediate environmental awareness.
- Simultaneously - the system will be accessed for pertinent information while targets are being engaged, allowing the soldier to focus on environmental awareness or on more globally related information that the system has to offer.

This duality of system use can be thought of as a trade-off between some of both types of awareness (simultaneous) versus all of one type of awareness (serial). In order for a soldier to use an information system simultaneously, he or she must have full trust in the sensor packages and any information being presented with which to make decisions in the combat environment. Transparent displays might add a level of relief. Auditory and visual icons can provide much reduction in information processing. Task analysis and link analysis may be performed on information systems to determine critical information requirements and to provide optimum human factors engineering design. If these systems will be used in combat, information must be “clean” and streamlined for efficient and safe use by soldiers.

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Appendix A: Demographic Data Form

DEMOGRAPHICS AND EXPERIENCE QUESTIONNAIRE

Subject Number _____

Age _____ Height _____ ft _____ in Weight _____ lbs

Rank _____ Date entered military (month) _____ (year) _____

Primary MOS _____ Secondary MOS _____

1. When was the last time you qualified with the M16A2 rifle?

_____ Month _____ Year

2. What is your current level of qualification as a rifleman based on the Army's or Marine's standard?

_____ expert _____ sharpshooter _____ marksman

3. Do you usually fire a rifle _____ left handed or _____ right handed? (Check one)

4. Do you use your _____ left eye or _____ right eye to aim a weapon?

5. Do you wear glasses or contact lenses when you shoot? _____ Yes _____ No (Check one)

6. Do you play video games or computer games?

_____ Yes _____ No

7. How well do you play video games?

_____ Poor _____ Below Average _____ Average _____ Above Average _____ Excellent

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Appendix B: SWAT Event Rating Form

SUBJECTIVE WORKLOAD ASSESSMENT TECHNIQUE

SUBJECT ID _____ TASK ID _____

(Mark an X in one choice for each of the three areas below that best describes what you believe the task workload to be.)

TIME LOAD

- ☐ 1 Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.
- ☐ 2 Occasionally have spare time. Interruptions or overlap among activities occur frequently.
- ☐ 3

Almost never have spare time. Interruptions or overlap among activities are frequent, or occur all the time.

MENTAL EFFORT

- ☐ 1 Very little conscious mental effort or concentration required. Activity is almost automatic requiring little or no attention.
- ☐ 2 Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.
- ☐ 3 Extensive mental effort or concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS

- 1

 Little confusion, frustration or anxiety exists and can be easily accommodated.
- 2

 Moderate stress due to confusion frustration or anxiety. Noticeably adds to workload. Significant compensation is required to maintain adequate performance.
- 3

 High to very intense stress due to confusion frustration or anxiety. High to extreme determination and self-control required.

Appendix C: Subjective Rating of Events (SRE) Form

SUBJECT ID: _____

TASK ID: _____

1. The scale below represents a range of how stressful an event might be. Put an “X” on the line to rate how much stress you experienced during the previous experimental trial?

Not at All
Stressful

Most Stress
Possible



2. At what number value does the “X” touch the line? _____

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Appendix D: Volunteer Agreement Affidavit

VOLUNTEER CONSENT FORM

Army Research Laboratory
Human Research and Engineering Laboratory
Aberdeen Proving Ground, MD

Log No.: _____

Title of Research Project: Study to Evaluate Physical and Cognitive Tasks and Measures for the Standardized Soldier Performance Test Paradigm

Principal Investigator: William Harper Phone: (410) 278-5955

Location of Study: Aberdeen Proving Ground, MD 21005

PURPOSE OF STUDY:

The purpose of this study is to evaluate and collect baseline data on the physical and cognitive tasks and measures to be used in a standardized dismounted soldier performance test paradigm. In the future, this set of tasks may be used to study uniforms, weapons, body armor, nutritional supplements, and soldier systems. During this pilot study, we will look at how long it takes to train and complete certain tasks, how long it takes to instrument the test participants, whether the physical activity levels are appropriate, and whether the cognitive tasks are appropriate and whether they interfere with the physical tasks.

PROCEDURE

1. Prior to your participation in this evaluation, the experimenters will ask you if you have had an injury, are on profile or have a medical problem that would preclude your participation in this study. If you have a medical problem or are on profile that could put you at risk in this study, you will not be allowed to participate.

2. You will be requested to participate in this evaluation from 16 to 27 October 2000. During this evaluation you will be asked to perform the following tasks: 4-km cross country course, 1-mile road march, 500-meter obstacle course, 100-meter individual movement technique course, sand bag course, zeroing and firing M16A2 rifle, field stripping M16A2 rifle, grenade throw for accuracy, cognitive tasks (such as a math, memory or logic questions) and stress questionnaires. Your working schedule will be Monday through Friday, 0700 to approximately 1600.

3. During the first day of the study, you will be trained to negotiate the cross country, obstacle, sandbag, and individual movement technique courses, throw a grenade for accuracy, field strip an M16A2, zero and fire an M16A2 at M-range, and perform the cognitive tasks and questionnaires. You will be given a safety briefing on the firing range. The experimenters will ensure that hearing protection devices are properly used by all personnel and test participants when they are at the firing range.

4. On all subsequent days you will perform the following:

0800 - 0815 Instrument and equip soldiers
0815 - 0830 Cognitive and stress battery (CPASE and MAACL)
0830 - 0840 Grenade throw
0840 - 0845 Sand bag course
0845 - 0945 Cross-country course

0945 - 1000 Obstacle Course
 1000 - 1030 1-mile Road march to M-range
 1035 - 1105 Two 18 target scenario
 1105 - 1125 M16A2 field stripping training
 1125 - 1155 1-mile Road march to KD Range
 1200 - 1220 Lunch
 1230 - 1330 Cross-country course
 1330 - 1350 Obstacle course
 1400 - 1420 IMT course
 1420 - 1430 Grenade throw
 1430 - 1435 Sand bag course
 1435 - 1450 Cognitive and stress battery (CPASE and MAACL)
 1450 - 1510 Equipment stowage and soldier interviews

5. You will be wearing BDUs and load carrying equipment. You will be wearing a fighting load of up to 58.20 pounds while negotiating the obstacle and individual movement technique courses. For the cross country and road marches, you will be required to carry a sustainment load of up to 98.2 pounds. During your march into the woods, the path will be clearly marked so that you do not get lost. There will be a person at the mid-point way to insure that you are in proper condition and to allow you to take a water break. You will be provided an air horn and will be asked to sound the horn if you are in need of assistance while on the cross-country course. It is recommended that you wear your old BDUs for the entire study since your BDUs will be subjected to accelerated wear and tear.

6. During the cross country course, obstacle course, road march and shooting tasks, you will be asked to perform cognitive tasks such as answering math questions, listening to information then answering questions about it, or monitoring simulated radio traffic for certain information. You will respond to these tasks either verbally or using a keypad to enter an answer.

7. Photographers will be taking pictures during this study. If you do not wish to have your photograph taken please inform the experimenters. If you agree to be photographed, steps will be taken so that you will not be able to be identified in any published photograph or produced videotape.

8. At anytime during this evaluation you may withdraw without penalty should you decide to do so.

9. The risks that will be encountered in this evaluation are minimal and are typical of the everyday risks encountered by soldiers performing their duties. For the shooter performance evaluation portion of the study, the risks include possible slight shoulder bruising and exposure to short duration high intensity noise from automatic weapons firing. The experimenters will ensure that hearing protection devices are properly used by all personnel and test participants when they are at the firing range. For the mobility study, these risks include physical fatigue, muscle strains, sprains, cuts, abrasions, broken bones, and skin irritations. During this study, you may be exposed to warm weather. Experimenters will monitor the wet-bulb temperature and activities will be suspended if the temperture is too hot. Care will be taken to minimize these risks using the following precautions.

Inclement Weather. If it is raining or snowing, or if there is an accumulation of water or snow on the HRED mobility portability course, daily test activities will be delayed or canceled.

Warm Weather. Experimenters will monitor the WGBT and follow the guidelines set forth by the ATC meteorology team.

Reporting of Problems. The test participants will be instructed to inform the experimenters of any problems that occur during the evaluation. They may be told to stop their activity until the problems are resolved.

10. All resulting data collected from you will be kept anonymous and confidential even when published in a report. Furthermore, you can have access to any of the data collected from you upon request.

11. Emergence care will be provided at the expense of the Army Research Laboratory if a medical emergency is encountered during this test that Kirk Army Clinic can not treat.

=====

It will be necessary to obtain your Armed Services Vocational Aptitude Battery (ASVAB) scores for potential data analysis. The ASVAB scores would be used strictly for study purposes and the results of this analysis would be presented for the group of participants as a whole and no names

would be used. With your permission, we would obtain these scores by sending a copy of this signed consent form along with your Social Security Number to the Defense Manpower Data Center (DMDC) in Monterey, CA, where ASVAB scores are maintained in a database. If you do not wish your ASVAB scores to be released to the principal investigator, you will still be allowed to participate in the study.

~~~~~  
If you would like to be in this study, please sign one of the following statements, and then complete the information requested at the end of this form:

I authorize you to obtain my ASVAB scores. \_\_\_\_\_  
(Your Signature)

I do NOT authorize you to obtain my ASVAB scores. \_\_\_\_\_  
(Your Signature)

=====

Any published data will not reveal your identity. Your participation in this study is voluntary. If you choose not to participate in this study, or if later you wish to withdraw from any portion of it, you may do so without penalty. Military personnel are not subject to punishment under the Uniform Code of Military Justice for choosing not to take part as human subjects. No administrative sanctions can be taken against military or civilian personnel for choosing not to participate as human subjects.

The furnishing of your social security number and home address is mandatory and necessary for identification and locating purposes to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this study. Information derived from this study will be used to document the study, to implement medical programs, to adjudicate claims, and for the mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State, and local agencies. Collection of this information is authorized by 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087. Under provisions of AR40-38 and AR 70-25, volunteers are authorized all necessary medical care for injury or disease which is the proximate result of their participation in this study.

Your signature indicates that you are at least 18 years of age, that you have read the information on this form, that you have been given the opportunity to ask questions, and they have been answered to your satisfaction, and that you have decided to participate based on the information provided on this form.

|                                                                                                                                                                        |      |                                |               |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|--------------------------------|---------------|
| I do <input type="checkbox"/> do not <input type="checkbox"/> (check one and initial) consent to the inclusion of this form in my outpatient medical treatment record. |      |                                |               |
| SIGNATURE OF VOLUNTEER                                                                                                                                                 | DATE | SOCIAL SECURITY NUMBER         | DATE OF BIRTH |
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## Appendix E: Meteorological Data

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| <b>2001 Date:</b>       | <b><u>Jan. 11</u></b> | <b><u>Jan. 12</u></b> | <b><u>Jan. 15</u></b> | <b><u>Jan. 16</u></b> | <b><u>Jan. 17</u></b> |
|-------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Mean Temp. (F)          | 44.4                  | 38.9                  | 39.9                  | 36.8                  | 33                    |
| Max Temp. (F)           | 55.4                  | 42.8                  | 42.8                  | 39.2                  | 35.6                  |
| Min. Temp (F)           | 30.2                  | 37.4                  | 37.4                  | 32                    | 30.2                  |
| Dewpoint (F)            | 18.6                  | 24.8                  | 39.2                  | 36.3                  | 25.8                  |
| Precipitation           | 0                     | 0                     | 0                     | 0                     | 0                     |
| Pressure (in.)          | 30.06                 | 30.19                 | 30.06                 | 29.97                 | 30.22                 |
| Wind Speed (mph)        | 9.21                  | 7.4                   | 1.73                  | 3.65                  | 4.35                  |
| Max Wind Speed<br>(mph) | 19.56                 | 11.51                 | 6.9                   | 6.9                   | 9.21                  |
| Gust Speed (mph)        | 26.47                 | n/a                   | n/a                   | n/a                   | n/a                   |



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## Appendix F: Multiple Regression Data (Linear)

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### **Friendly Target Engagement Percentage Prediction.**

| <u>Individual Variables</u>           | <u>Method</u> | <u>df</u> | <u>F</u> | <u>sig.</u> | <u>r<sup>2</sup></u> |
|---------------------------------------|---------------|-----------|----------|-------------|----------------------|
| Cognitive Load (CL) 0=no load, 1=load | Stepwise      | 1,142     | 103.74   | .000        | .10                  |

Friendly Target Engagement Percentage Prediction =  $0.194 + (0.792 * CL)$

### **Math Task Completion Prediction.**

| <u>Individual Variables</u>           | <u>Method</u> | <u>df</u> | <u>F</u> | <u>sig.</u> | <u>r<sup>2</sup></u> |
|---------------------------------------|---------------|-----------|----------|-------------|----------------------|
| Target Exposure Time (TET) 2,3,or 4 s | Stepwise      | 1,70      | 5.83     | .018        | .08                  |

Math Task Performance as a Secondary Task =  $12.86 + (1.167 * TET (s))$

| <u>Individual Variables</u>            | <u>Method</u> | <u>df</u> | <u>F</u> | <u>sig.</u> | <u>r<sup>2</sup></u> |
|----------------------------------------|---------------|-----------|----------|-------------|----------------------|
| Target Exposure Time (TET) 2,3,or 4 s  | Stepwise      | 2,69      | 6.00     | .004        | .15                  |
| Friendly Target Signature (FTS) (W, G) |               |           |          |             |                      |

Math Task Performance as a Secondary Task =  $12.86 + (1.167 * TET (s)) - (1.83 * FTS)$

### **Hit Percentage Prediction.**

| <u>Individual Variables</u>           | <u>Method</u> | <u>df</u> | <u>F</u> | <u>sig.</u> | <u>r<sup>2</sup></u> |
|---------------------------------------|---------------|-----------|----------|-------------|----------------------|
| Target Exposure Time (TET) 2,3,or 4 s | Stepwise      | 1,142     | 195.35   | .000        | .58                  |

Hit Percentage as a Secondary Task =  $-1.54 + (2.885 * TET (s))$

### **Reaction Time (First Shot) Prediction.**

| <u>Individual Variables</u>           | <u>Method</u> | <u>df</u> | <u>F</u> | <u>sig.</u> | <u>r<sup>2</sup></u> |
|---------------------------------------|---------------|-----------|----------|-------------|----------------------|
| Target Exposure Time (TET) 2,3,or 4 s | Stepwise      | 1,142     | 103.74   | .000        | .42                  |

Reaction Time Prediction =  $1.271 + (0.297 * TET (s))$

Forward stepwise multiple linear regressions (p to enter = .05 and remove = .10) were performed using the following variables as possible predictors: Cognitive workload level (coded 1 = low, 2 = moderate, 3 = high) and Shooting condition (1 = shooting, 2 = not shooting). These analyses were run to predict secondary (math and SA) task performance, SWAT workload ratings, and SRE stress ratings. No values were missing, therefore none were replaced.

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## Appendix G: McCracken-Aldrich Workload Scaling of Tasks Performed

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### TASK WORKLOAD ESTIMATES

Primary Task - Shooting Task (performed 24 times in 2 min)

|                        | <u>Visual</u> | <u>Cognitive</u> | <u>Auditory</u> | <u>Psychomotor</u> | <u>Total</u> |
|------------------------|---------------|------------------|-----------------|--------------------|--------------|
| Scan for Targets       | 7.0           | 3.7              | 0.0             | 2.6                | 13.3         |
| Target Acquisition     | 3.7           | 3.7              | 0.0             | 0.0                | 7.4          |
| Enemy Target?          | 3.7           | 3.7              | 0.0             | 0.0                | 7.4          |
| Don't Fire             | 0.0           | 3.7              | 0.0             | 0.0                | 3.7          |
| Aim at Target          | 5.0           | 4.6              | 0.0             | 2.6                | 12.2         |
| Sight Picture OK?      | 3.7           | 3.7              | 0.0             | 0.0                | 7.4          |
| Re-Align Sights or Aim | 5.0           | 4.6              | 0.0             | 2.6                | 12.2         |
| Fire Weapon at Target  | 5.0           | 1.0              | 0.0             | 2.6                | 8.6          |
| Target Hit?            | 1.0           | 1.2              | 0.0             | 0.0                | 2.2          |
| Another Target?        | 1.0           | 1.2              | 0.0             | 0.0                | 2.2          |
| End Scenario?          | 1.0           | 1.2              | 1.0             | 0.0                | 3.2          |

Secondary Task – Mathematical Problems (performed 20 times in 2 min)

|                   |     |     |     |     |     |
|-------------------|-----|-----|-----|-----|-----|
| Listen to Problem | 0.0 | 3.7 | 4.9 | 0.0 | 8.6 |
| Calculate Answer  | 0.0 | 7.0 | 0.0 | 0.0 | 7.0 |
| Time Left (tone)? | 0.0 | 3.7 | 1.0 | 0.0 | 4.7 |
| Speak Answer      | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 |
| Skip Problem      | 0.0 | 3.7 | 0.0 | 0.0 | 3.7 |
| End Scenario?     | 1.0 | 1.2 | 1.0 | 0.0 | 3.2 |

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## **Appendix H: Task Workload Calculations for IMPRINT Modeling**

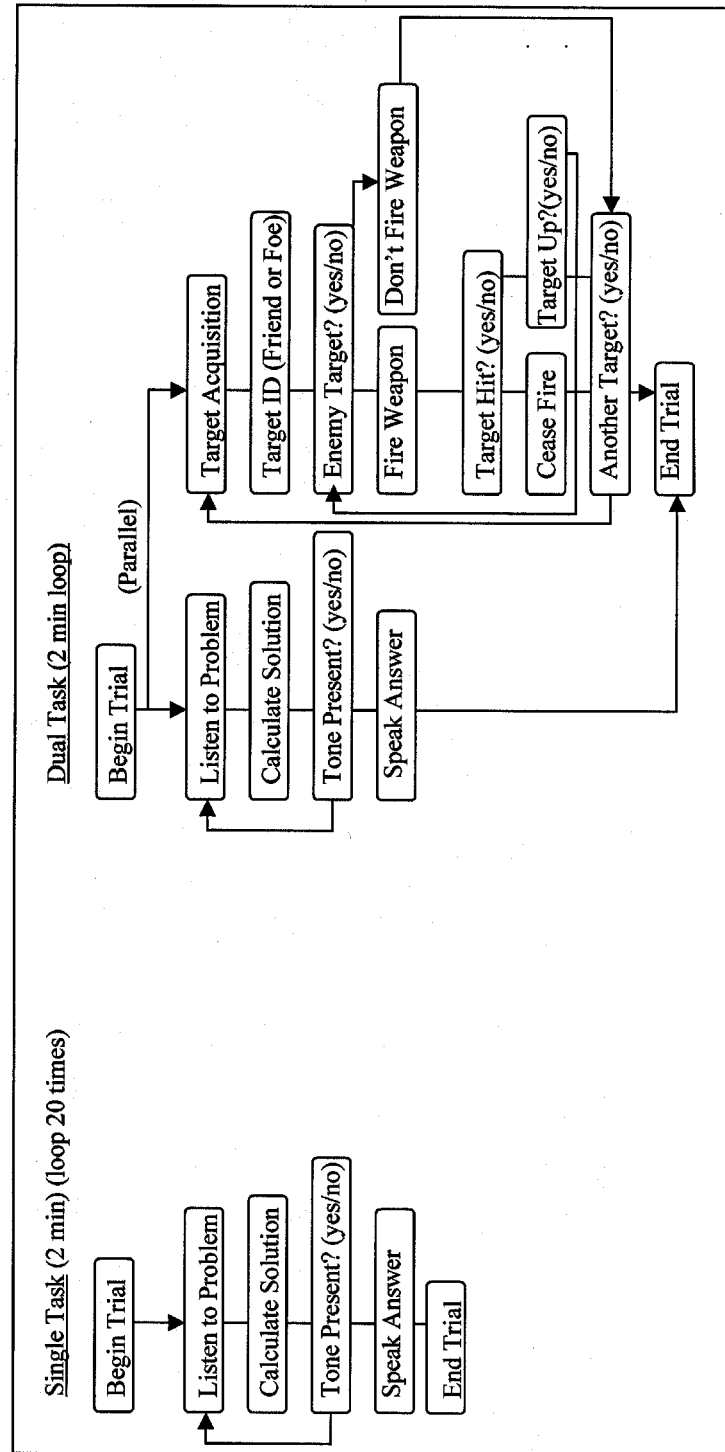
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Shooting + Math Task - Dual Task Formula:  $V + C + A + P + N$  (number of tasks) = total workload for each task

$$\text{Level (Moderate Difficulty)} = V + C (1.40) + A + P + N$$

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## Appendix I: Task Flow Network for Single and Dual Tasks





| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                             |                              |                                         | Form Approved<br>OMB No. 0704-0188                         |                                                           |
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| 14. ABSTRACT<br>The current study proposed to alter friendly target visual signatures and target exposure times to examine the possible interaction effects of a shoot-don't shoot friend and foe target discrimination task under cognitive load. These trials were performed as a single-task scenario and as a dual-task scenario under one level of cognitive workload with a secondary task. Participants were 12 U.S. Army infantry Soldiers, military occupational specialty 11M (mechanized), whose ages ranged from 18 to 34 years old.<br>The friendly and enemy target set in each trial was a 24-target scenario that used friendly (varied as white or gray circular marking on the chest of the target) and enemy (olive drab green) E-type silhouette targets. Half of the targets were friendly and half were enemy. Ranges consisted of 50, 100, 150, 200, 250, and 300 meters and target exposure times were 4, 3, and 2 seconds.<br>The secondary task, mathematical problem solving, was presented aurally while subjects performed shooting tasks. Dependent variables included overall hit percentage, reaction time, and friendly targets engaged. Also included were subjective workload stress ratings. Analysis of variance and regression analyses revealed significant differences for a number of performance and subjective data. |                             |                              |                                         |                                                            |                                                           |
| 15. SUBJECT TERMS<br>cognitive workload, dismounted warrior, fratricide, mental workload, secondary task, shooting performance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                             |                              |                                         |                                                            |                                                           |
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